USAFSAM-TR-86-11

AD-A171 698

CAN "HIGH TECH" SUBORDINATE NUMERICAL SUPERIORITY?

Richard A. Albanese, M.D.

July 1986

Final Report for Period October 1984 - September 1985

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, TX 78235-5301

NOTICES

This interim report was submitted by personnel of the Radiation Analysis Branch, Radiation Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 7755-26-32.

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility nor any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

Richard A. Albanese, M.D.
RICHARD A. ALBANESE, M.D.
Project Scientist

John C Mitchell
JOHN C. MITCHELL
Chief, Radiation Sciences Division

Jeffrey G. Davis
JEFFREY G. DAVIS, Colonel, USAF, MC
Commander

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

ADA171698

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAFSAM-TR-86-11	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAF School of Aerospace Medicine 6b. OFFICE SYMBOL (If applicable) USAFSAM/RZM	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Aerospace Medical Division (AFSC) Brooks Air Force Base, TX 78235-5301	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION USAF School of Aerospace Medicine 8b. OFFICE SYMBOL (If applicable) USAFSAM/RZM	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Aerospace Medical Division (AFSC) Brooks Air Force Base, TX 78235-5301	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 62202F PROJECT NO. 7755 TASK NO. 26 WORK UNIT ACCESSION N[illegible] 32

11 TITLE (Include Security Classification)
Can "High Tech" Subordinate Numerical Superiority?

12. PERSONAL AUTHOR(S)
Albanese, Richard A.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Interim	FROM Oct 84 TO Sept 85	1986, July	12

16 SUPPLEMENTARY NOTATION
Submitted in the 1985 AFSC WARRIOR Commander's Distinguished Paper Competition.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	
12	02		
15	07		Lanchester models, Combat models

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The Soviet Union presents a military force with significant numerical superiority relativ[e] to United States' military forces. This report concludes that technical superiority can subordinate numerical superiority under particular conditions, in the context of Lancheste[r] models. For battle at a coherent front the technical advantage of the "high tech" force [m]ust have to be much greater than the numerical advantage possessed by the opponent. At equal fighting strength a "high tech" force could be more expensive than a "low tech" force unl[ess] greater production efficiency can be achieved. Lastly, the "high tech" option may be wea[k] against a primitive force using guerrilla tactics. The propositions elaborated in this report are tentative and must be developed by more detailed historical and operations anal[y]sis.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL RICHARD A. ALBANESE	22b. TELEPHONE (Include Area Code) 512/536-3583 22c. OFFICE SYMBOL USAFSAM/RZM

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.
All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

CAN "HIGH TECH" SUBORDINATE NUMERICAL SUPERIORITY?

INTRODUCTION

The Soviet Union presents a military force with significant numerical superiority relative to United States' military forces (3). This report considers whether technical superiority can compensate for Soviet numerical superiority.

Historical research and analysis is one important approach to addressing the question of whether technical superiority can reliably compensate for numerical deficiency. Previous military conflicts can be studied in depth to evaluate the separate but interacting roles of technical and numerical strength. For example, it is my perception that both the 1973 Middle East war and Falkland war were conflicts where the technically superior force prevailed over the numerically superior military system. On the other hand, it is my opinion that the technologically superior force was at least partially thwarted in Vietnam, and a similar situation is occurring in Afghanistan.

In addition to historical analysis, detailed computer-based operations research modeling and systems field testing might also be employed to evaluate the "high tech" option. However, before either historical analysis or future-oriented operations research is pursued, it may be appropriate to set out some basic propositions or hypotheses which the more detailed analyses would confirm, refute, or refine. The development of these starting-point propositions or hypotheses is the purpose of this report.

THE LANCHESTER N-SQUARE LAW

Following the simple formulation of Lanchester, consider two opposing forces, Blue force versus Red force (6). With the two forces meeting across a single front, to crude first-order approximation, the rate of attrition of the Blue force should be roughly proportional to the size of the Red force, that is

$$dB/dt = - v \cdot R \tag{1}$$

where B is the size of the Blue force, R is the size of the Red force, and v is Blue force vulnerability or, equivalently, is Red force capability. Similarly, as a first approximation,

$$dR/dt = - c \cdot B \tag{2}$$

where c is Blue force capability.

Equations 1 and 2 can be solved simultaneously to obtain equations 3 and 4:

$$B(t) = (1/2\sqrt{c})\{(\sqrt{c}\ B_0 + \sqrt{v}\ R_0)\exp(-\sqrt{cv}\ t) + (\sqrt{c}\ B_0 - \sqrt{v}\ R_0)\exp(+\sqrt{cv}\ t)\} \tag{3}$$

$$R(t) = (1/2\sqrt{v})\{(\sqrt{c}\ B_0 + \sqrt{v}\ R_0)\exp(-\sqrt{cv}\ t) + (\sqrt{v}\ R_0 - \sqrt{c}\ B_0)\exp(+\sqrt{cv}\ t)\} \tag{4}$$

In these equations B_0 and R_0 are the sizes of the Blue force and Red force respectively at time $t = 0$, the start of combat. Equations 3 and 4 show that the Red force can be reduced to nil if cB_0^2 is greater than vR_0^2, and conversely the Blue force can be reduced if cB_0^2 is less than vR_0^2. This observation is the core of Lanchester's "n-square law" which states that two opposing forces are of equal fighting strength if the products

$$\text{capability} \times (\text{size})^2$$

are equal (i.e., if $cB_0^2 = vR_0^2$).

Rather than using equations 3 and 4, the notion of fighting strength can be developed in another way. Two forces are of equal military strength if their relative rates of loss are the same, that is, if

$$\frac{1}{B}\frac{dB}{dt} = \frac{1}{R}\frac{dR}{dt} \tag{5}$$

By substituting equations 1 and 2 into equation 5, the relationship $cB_0^2 = vR_0^2$ is again obtained as a condition of equal force strength.

If the Blue force is a successful "high tech" force, its capability c will exceed its vulnerability v so that an initial numerical inferiority (B_0 less than R_0) can be offset. However, if, for example, the Red force is twice the size of the Blue force, Blue force capability to inflict damage (c) must be <u>four</u> times its vulnerability (v). Thus, my first proposition or hypothesis emerges:

> **For battle at a coherent front, a "high tech" force can defeat superior numbers; however, the technical advantage of the "high tech" force (c/v) will have to be much greater than the numerical advantage (R_0/B_0) possessed by the opponent.**

This hypothesis asserts that a technological advantage can be offset by a numerical response. Thus a specific technological advance may be of value

only for a limited time, and continuous research and development effort is required. While research and development projects can be planned and managed, the outcome of such projects cannot be deterministically known because of the role of the unexpected in technological advance. Thus strengthening a military force by technological improvements only is subject to greater uncertainty than is strengthening by numerical increase, although the possibility of a quantum leap in technological capability is always present. Thus, a mix of technological and numerical strengthening may be elected. However, while pointing to the desirability of a combined focus on technological and numerical strength, the great importance of technological research and development must not be diminished, particularly because of the possibility of technological surprise which could radically alter any balance of power.

"HIGH TECH" AND COST

The cost of a military force is directly related to the capability of its elements and the number of elements possessed. Assume equal dollar value for each unit of military capacity and symbolize this value by kappa (κ). Then the cost of Blue force is κcB_0, and the cost of Red force is κvR_0. If the forces are of equal military strength, $cB_0^2 = vR_0^2$, but this equality implies that

$$\kappa cB_0 > \kappa vR_0$$

when Blue force is technologically superior ($c/v > 1$) but numerically inferior ($R_0/B_0 > 1$). In summary I hypothesize that:

> **Costs for a "high tech" force will be greater than the costs for an equal-strength "low tech" force, unless the "high-tech" force also achieves greater efficiency in military production.**

The costs alluded to in this hypothesis are hardware and training costs, but neglect human life values. The question of personnel losses will be touched on in a subsequent section. The condition of equal dollar value for each unit of military capacity is unlikely to obtain in practice. On one hand, a technologically advanced nation fielding a high-tech force may have a higher standard of living and generally higher labor costs. On the other hand, automation of production and similar technological innovations can reduce weapons' production costs.

"HIGH TECH" AND GUERRILLA WARFARE

Another important consequence can be suggested from the very simple Lanchesterian approximation. My first two propositions were developed in the setting of war across a coherent battlefront by two homogeneous clashing forces. If the technically primitive force is able to string out the "high tech" force over a disjointed, incoherent battlefront and, using mobility and terrain cover, is able to attack only when possessing a significant numerical advantage, the primitive force can be victorious. Equations 3 and 4 can be applied to illustrate this assertion, and the results are surprising.

B_0 and R_0 are the sizes of the entire Blue and Red forces respectively at the beginning of conflict. In equations 3 and 4 replace B_0 by B_0' and R_0 by R_0' where the primed symbols refer to subunits of the total forces. Assume that R_0' is sufficiently greater than B_0' to offset any technological advantage the Blue force may possess; that is, let $vR_0'^2$ be greater than $cB_0'^2$. Then the Blue force subunit with initial size B_0' can be reduced to nil in time t*, where t* is computed from equation 3 as

$$\exp(-\sqrt{cv}\ t^*) = \sqrt{\frac{\sqrt{v}\ R_0' - \sqrt{c}\ B_0'}{\sqrt{v}\ R_0' + \sqrt{c}\ B_0'}} \tag{6}$$

By substituting equation 6 into equation 4, it is apparent that the Red force subunit size, after its destruction of the Blue unit, is $R'(t^*)$ where

$$R'(t^*) = R_0'\sqrt{1 - cB_0'^2/vR_0'^2} \tag{7}$$

Specific cases can be studied using equation 7. For example, consider the Blue force to be technologically superior with $c/v = 6$ comfortably offsetting Red force numerical superiority, $R_0/B_0 = 2$. Suppose a portion of the Red force is able to attack a small subunit of the Blue force. Specifically, suppose $B_0' = 0.02\ B_0$; that is, suppose that the Blue subunit attacked is 2% of the total Blue force. If the Red force attacks the Blue subunit with a 10% subunit force of its own, we have $R_0' = 0.10\ R_0$. Substituting these values for R_0' and B_0' into equation 7 and remembering that $c/v = 6$ and $R_0/B_0 = 2$, we find that $R'(t^*) = .97\ R_0' = 0.097\ R_0$; that is, the Red force has destroyed 2% of the Blue force while losing only 0.3% of its own force. Fifty such engagements would completely reduce the Blue force while the Red force would sustain loss of only 15% of its total force. Thus the following extremely important proposition emerges:

> **A technically and numerically inferior force can defeat a "high tech" force, if the more primitive force can require the "high tech" force to fight across a diffuse battlefront, and the primitive force can choose to fight only when it has local numerical superiority.**

It is certainly possible that future technological breakthroughs will enable more effective countering of guerrilla-like activities. For example, if enemy combatants could be remotely tracked, irrespective of cover, by a personal, possibly electromagnetic signature, ambushing and surprise attacks could be minimized, and combatants could be culled from protecting populations.

"HIGH TECH" AND PERSONNEL LOSSES

Equation 7 provides an estimate of Red force losses after defeating a Blue force component. In fact $R'(t^*)/R_0'$ can be interpreted as a probability: specifically, the probability of surviving the particular engagement. An analogous equation can be written to provide an estimate of Blue force losses after defeating a Red force component, and is given in equation 8 where

$$B'(t^*) = B_0' \sqrt{1 - vR_0'^2/cB_0'^2} \tag{8}$$

Again, $B'(t^*)/B_0'$ can be interpreted as a probability of engagement survival.

In studying equations 7 and 8, some very interesting considerations emerge. If given a choice between weapons, it is quite understandable that an airman or ground soldier would choose to employ the weapon with greatest effectiveness, both out of a concern for self-defense and to be of assistance to his cause and comrades-in-arms. Such an intuitive choice gains force by reference to equations 7 and 8, since in one-on-one or equal group engagements ($R_0' = B_0'$) the individual with the best weapon has highest probability of survival. However, if weapons' costs are so high that you are asked to serve in a reduced force which faces an adversary with a numerical advantage that outweighs your technological superiority in most engagements, self and group interest might suggest fielding of lesser weapons in greater quantity. This conclusion also follows from equations 7 and 8, since losses are seen there to be a function of relative fighting strengths, involving products of both weapons' capability and force size (squared). These thoughts clearly intersect concerns of the national economy with complex issues regarding human life values. In any case, it seems important to consider that, at least in some military instances, the use of greater numbers may spare lives as effectively as does the introduction of new technology.

ALTERNATIVE ASSUMPTIONS

The preceding discussions follow from the assumption that loss rates are directly proportional to adversary size. This assumption leads to an emphasis on an interaction between technological quality of weapons and numerical availability. Is this interaction a quirk of the starting assumption?

Lanchester propounded a second model that addresses long-range fire targeting an area containing enemy forces, rather than targeting enemy forces per se (6). This model is given below, using the same symbols defined before:

$$\frac{dB}{dt} = -vRB$$

$$\frac{dR}{dt} = -cRB$$

Since equal attrition rates $\left(\text{i.e., } (1/B)dB/dt = (1/R)dR/dt\right)$ imply equal fighting strengths, it is found in this model that Blue fighting strength is $c \cdot B_0$ and Red fighting strength is $v \cdot R_0$. Thus for the case of long-range area-targeted fire, weapons' capability and weapons' numbers are on a more equal footing (B_0 and R_0 are no longer squared). Nonetheless, the intimate interaction of technology and numbers is still seen in this formulation, as well as in other variants of Lanchester's approach (4,5). Thus, I tentatively conclude that the dependence of fighting force on both weapons' quality and quantity will be found across a significant range of conflict situations.

QUALITATIVE CONSIDERATIONS

Thus far I am provisionally arguing that "high tech" forces can subordinate numerical superiority but with due regard for numerical counteraction, cost, and guerrilla-type actions. Two other cautions will be brought forward now.

First, a military system that greatly focuses on technology could potentially find itself stocked with personnel who are expert engineers, operations analysts and managers, but with very few individuals whose concern is military art and science (2). The American editor of Sidorenko's text, The Offensive, states that: "No graduate degrees in the United States are given in the field of military science" while in the Union of Soviet Socialist Republics: "There probably are several hundred officers who have been awarded the degree Candidate of Military Science" (1). Does this reported, apparent lack of advanced military science training in the United States represent an important vulnerability?

Second, a "high tech" military system could be so sophisticated that average members of a nation's population would not grasp basic military concepts and necessities without help, and thus the military might become an esoteric, detached entity without a base of support. This concern highlights the need for extensive military-to-citizen communication.

These two qualitative considerations further moderate the concept of a "high tech" force. These considerations do not minimize the importance of technology, but rather place technology in a broader framework. Again, weapons' capability based on technology is an important force multiplier and the problem of technological surprise is serious. Thus research and development efforts must be pursued without pause. System procurement and deployment, whether "high tech" or not, may occur as dictated by mission requirements, resource availability, economics, politics, and innumerable other considerations delicately balanced.

CONCLUSION

Starting from the assumption that attrition of one's forces will be roughly proportional to the size of one's opponent, with the constant of proportionality reflecting the adversary's capability, I have been able to infer three propositions about the "high tech" option. I provisionally conclude that "high tech" can subordinate Soviet numerical superiority. However, this dominance over numerical superiority may occur only if our technical superiority significantly outstrips our numerical inferiority. Roughly, if we are half as large, we might require ourselves to be more than four times as good. The "high tech" option may be more expensive if parity is achieved, unless greater production efficiency can be accomplished. Lastly the "high tech" option may be weak against an enemy who can skillfully employ tactical retreat, hiding in terrain, or who can live within a population considered not targetable.

The propositions put forward here are the result of earnest but limited analysis. Since the formulation of the propositions used deterministic expressions, probabilistic elements such as readiness and weapons reliability have not been addressed. In any case, the propositions put forward should be seriously challenged by careful historical research and analysis, and by detailed operations analysis and test of current systems. I perceive through personal experiences in these domains, that military success is an intricate weave of quantity and quality, and that balanced development of both is required. We must provide each airman with weapons and skills which are optimally effective in each of the threat environments he may face, but great care must be taken that this is done in sufficient numbers.

REFERENCES

1. American Editor's Comment in The Offensive (A Soviet View), by A.A. Sidorenko, U.S. Government Printing Office, Washington, DC 20402.

2. Baucom, D. R. "Technological War, Reality and American Myth." Air University Review, Vol. 32, pp. 56-66, Sept-Oct 1981.

3. Collins, J. M. U.S. - Soviet Military Balance. Concepts and Capabilities 1960-1980. New York: McGraw Hill Publications Company, 1980.

4. Hagues, J. N. "Stochade-A Highly Aggregated and Stochastic Combat Model" pp. 637-656, in Systems Analysis and Modeling in Defense, edited by Reiner K. Huber. New Jersey: Plenum Press, 1984.

5. Haysman, P. J. and Wand, K. "Extensions to Lanchester Theory of Combat," pp. 577-585, in Systems Analysis and Modeling in Defense, edited by Reiner K. Huber. New Jersey: Plenum Press, 1984.

6. Lanchester, F. W. "Mathematics in Warfare" in The World of Mathematics, Vol. 4, pp. 2138-2157. Presented by James R. Newman. New York: Simon and Schuster, 1956.